Report to the Director, Governor's Office of Emergency Services
By the California Earthquake Prediction Evaluation Council
March 2, 2004

The Governor's Office of Emergency Services requested that the California Earthquake Prediction Evaluation Council meet to evaluate an earthquake prediction proposed by Dr. Vladimir Keilis-Borok and colleagues. The Council met on February 20, 2004.

The prediction is for a magnitude 6.4 or greater earthquake to occur on or before September 5, 2004, within a 12,440 sq. miles area of southern California that includes portions of the eastern Mojave Desert, Coachella Valley, Imperial Valley (San Bernardino, Riverside and Imperial Counties) and eastern San Diego County (Figure 1).

The area of the southern California prediction includes a number of very active faults, including the Coachella segment of the San Andreas fault, the southern portion of the San Jacinto fault, the Imperial fault, and a portion of the Elsinore fault. Based on the geologic recurrence rates and the dates of previous earthquakes, earth scientists generally agree that both the Coachella segment of the San Andreas fault and the Anza segment of the San Jacinto fault are areas where large earthquakes are likely in the near future (1995 report of the Working Group on California Earthquake Probabilities). The area is one of the most seismically active in the state. It includes the recent Landers (M7.3) and Hector Mine (M7.1) earthquakes, which continue to have significant aftershock activity. There were 8 earthquakes with $M \geq 6.4$ in the area of the southern California prediction during the last 60 years of the 20^{th} century. The probability of a $M \geq 6.4$ earthquake occurring in a random 9-month period is thus estimated to be about 10% (see Technical Note1, below).

The Keilis-Borok et al. method is based on identifying patterns of small earthquakes prior to large shocks. Technical details of the prediction methodology are summarized in Technical Note 2.

In mid-2003, the Keilis-Borok group issued two earthquake predictions using variants of this methodology, one for a $M \geq 7.0$ earthquake in a 250,000 sq. mi. area that includes the northern part of the Japanese islands and one for a $M \geq 6.4$ earthquake in a 40,000 sq. mi. area that includes portions of central California. These two predictions were satisfied by the September 25, 2003 Hokkaido and December 22, 2003 San Simeon earthquakes, respectively. CEPEC notes that these were "proper" predictions, in that the authors specified in advance the area, time interval, and magnitude range satisfied by the subsequent events. However, the authors did not provide formal estimates of the probability gain over random occurrence with their predictions (see Technical Note 3). The Japan prediction area is very seismically active; 12 $M \geq 7.0$ earthquakes occurred in this area during the 30 years from 1974 through 2003, which yields a 30% probability for a random occurrence. The central California area has been much less active; only three $M \geq 6.4$ events (1906 San Francisco, 1983 Coalinga, and 1989 Loma Prieta) have occurred during the last hundred years, and 6 to 7 in the last 150 years. Therefore, the probability of a M≥6.4 earthquake in the specified area during a random 9-month period is about 2% to 5%.

The Keilis-Borok methodology appears to be a legitimate approach in earthquake prediction research. However, the physical basis for the prediction put forward by the authors has not been substantiated, and they have not yet issued enough predictions to allow a statistical validation of their forecasting methodology. Continued research along these lines may lead to useful forecasts. Although the analysis has matured to the point of generating provocative scientific results, the absence of an established track record and the sensitivity of the results to input assumptions leaves CEPEC uncertain of the robustness of the prediction made using patterns of small earthquakes.

This uncertainty along with the large geographic area included in the prediction (about 12,400 sq. mi.) leads CEPEC to conclude that the results do not at this time warrant any special public policy actions in California. Nevertheless, the southern California prediction, as well as the recent San Simeon earthquake, should serve to remind all Californians of the significant seismic hazards throughout the state. Regardless of the validity of the prediction, CEPEC recommends that all jurisdictions review and periodically exercise existing preparedness and response plans. Likewise, citizens of California who live in areas of high seismic hazard should make sure they have undertaken all general preparedness actions recommended by emergency management organizations and the Red Cross.

Technical Notes

1. The best estimate of 10% assumes earthquakes occur randomly in time; i.e., according to a Poisson process. Under this assumption, the 90% confidence interval for the estimate is 4-18%.

2. The Keilis-Borok et al. prediction for southern California is based on identifying patterns of small earthquakes ("chains" of $M \geq 2.9$ earthquakes) that have been observed to precede $M \geq 6.4$ earthquakes in California. Chains that are large enough (more than 6 events spanning more than 175 km) are tested using a retrospective analysis that searches for precursory patterns of seismicity during the preceding 2-5 years. If a chain "qualifies" by having a high enough score in terms of these possible intermediate-term precursors, a prediction is issued for the 9-month interval immediately following the last event of the chain. In the case of the southern California prediction, the chain comprised 10 earthquakes, and the last event occurred on December 5, 2003.

3. From the retrospective analysis of the California earthquake catalog for 1965-2003, the Keilis-Borok group derived a false-alarm rate of about 33% (5 out of 15 qualified chains were false alarms), and they claimed no failures to predict. An analysis restricted to southern California yielded a false-alarm rate of 13% (1 in 8 qualified chains was a false alarm). The associated probability gains were a factor of about 10 and 12 over random occurrence, respectively. In the case of the Japan prediction, the retrospective false- alarm rate was 41% (7 of 17), and the probability gain was a factor of about 7. All of these statistics are subject to large errors; moreover, they are likely to be biased toward optimistic values, because the prediction algorithm was tuned to optimize the retrospective analysis.

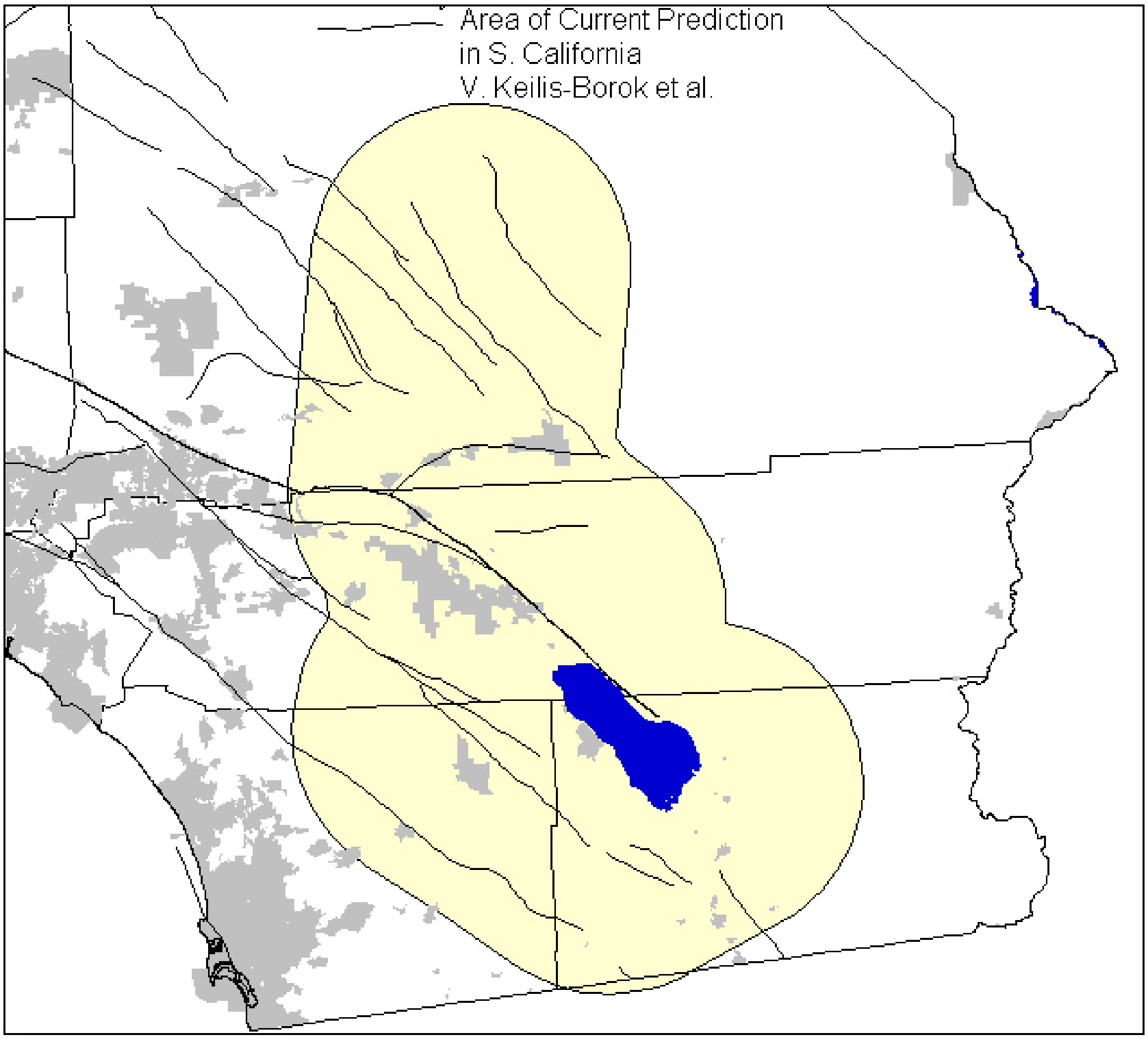
Area of Current Prediction
in S. California
V. Keilis-Borok et al.

Figure 1.